



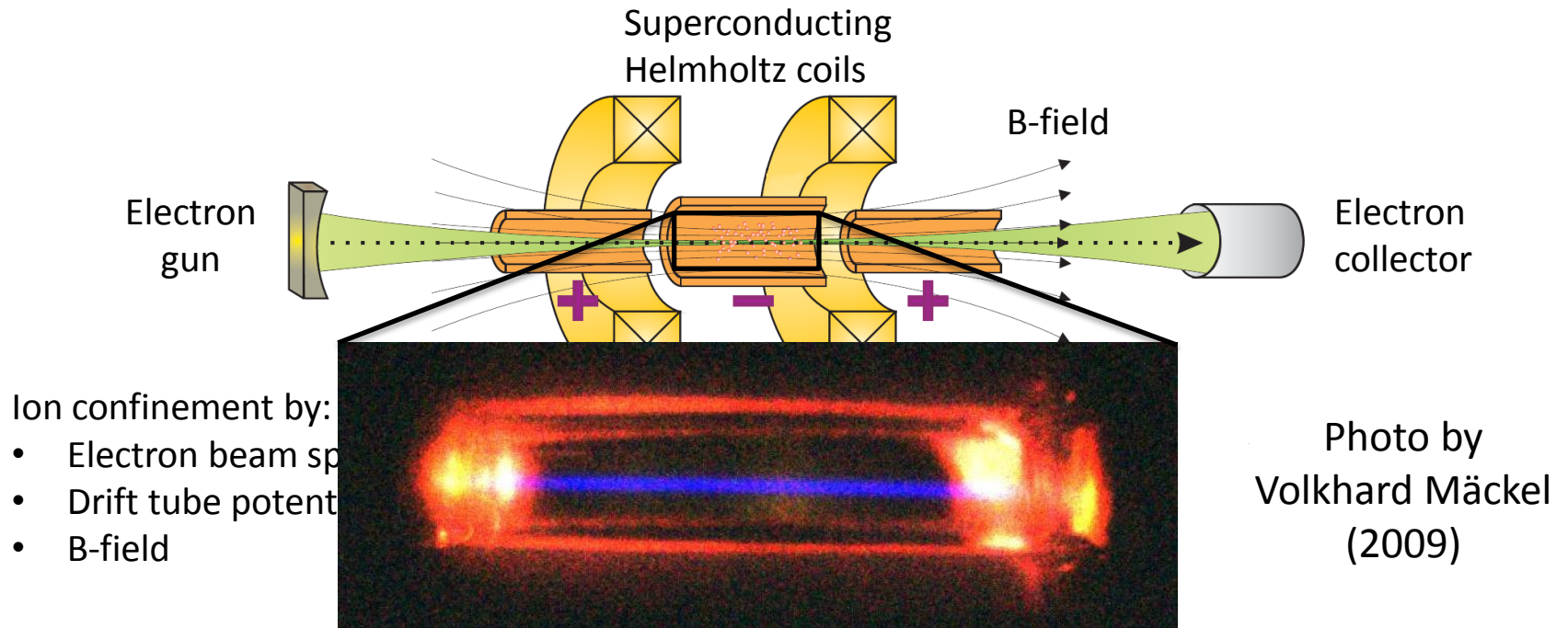
Fundamental studies of Sn^{7+} - Sn^{14+} ions with applications for laser produced plasma sources

Hendrik Bekker

EUV Source Workshop - Dublin

1. Discussion of published results
2. What more can be done with EBIT?

The electron beam ion trap (EBIT)



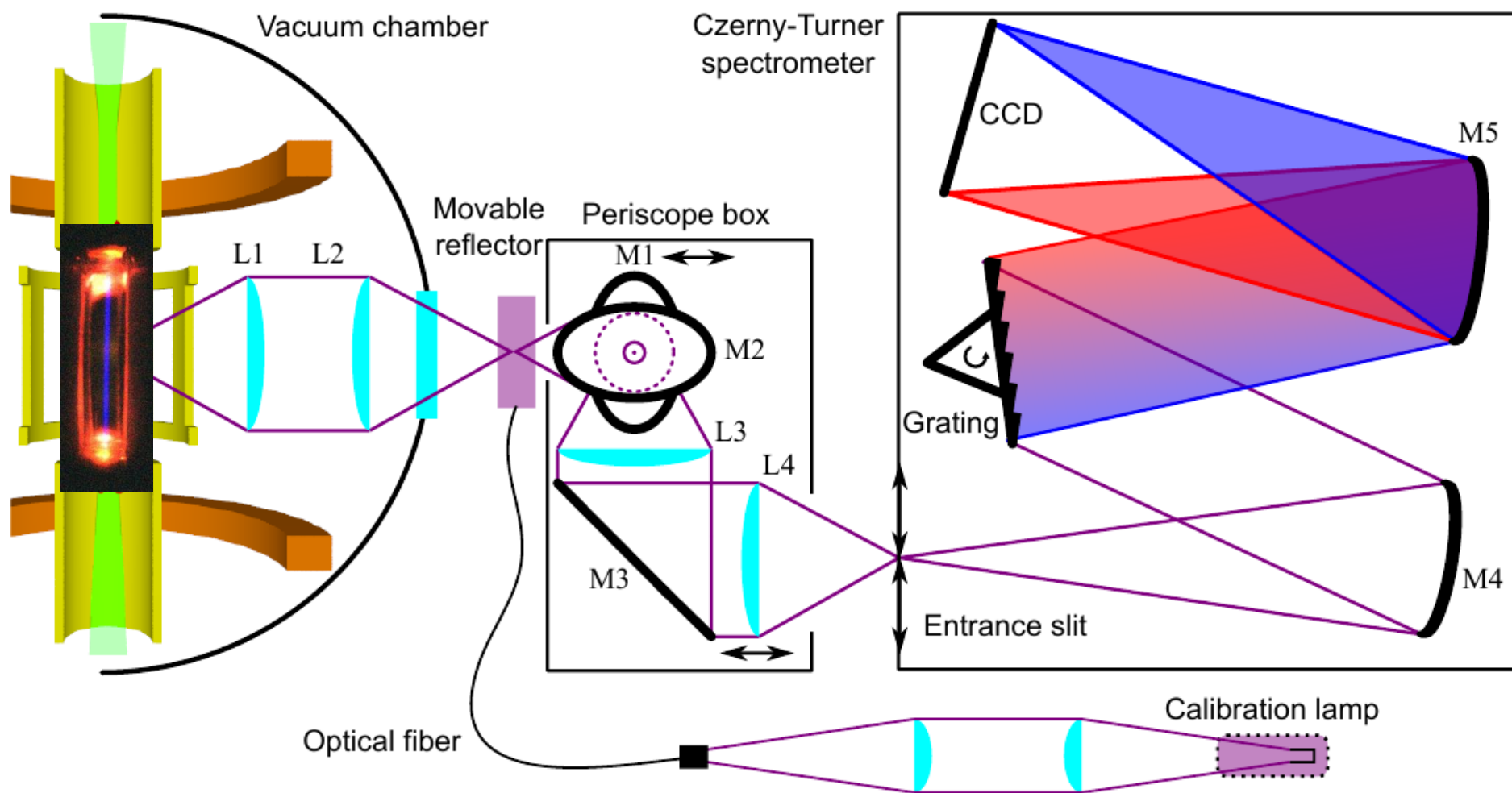
Ionization to charge state $q+$ by electron impact *ionization*:

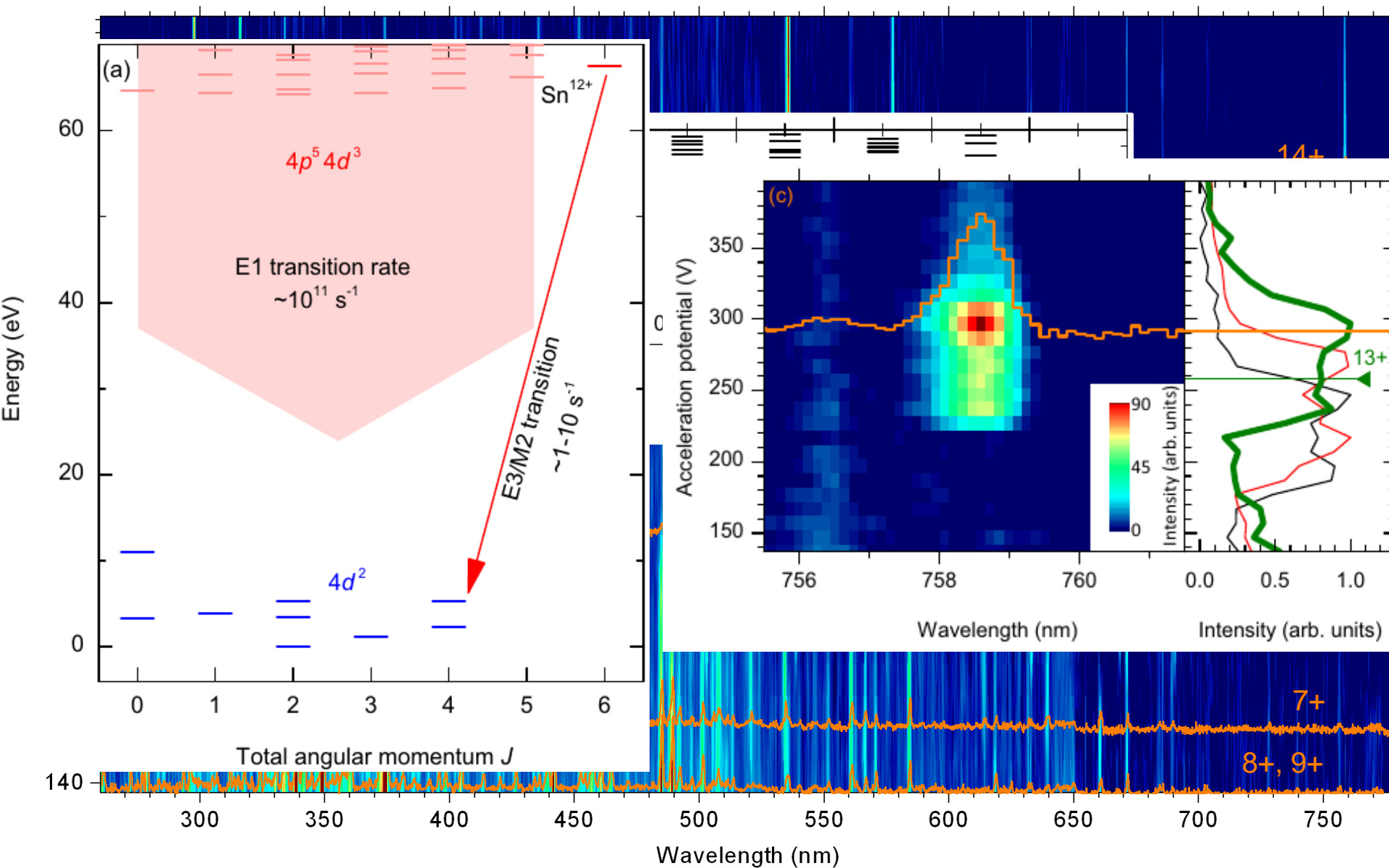
$$E_e \geq E_{ion}(q+)$$

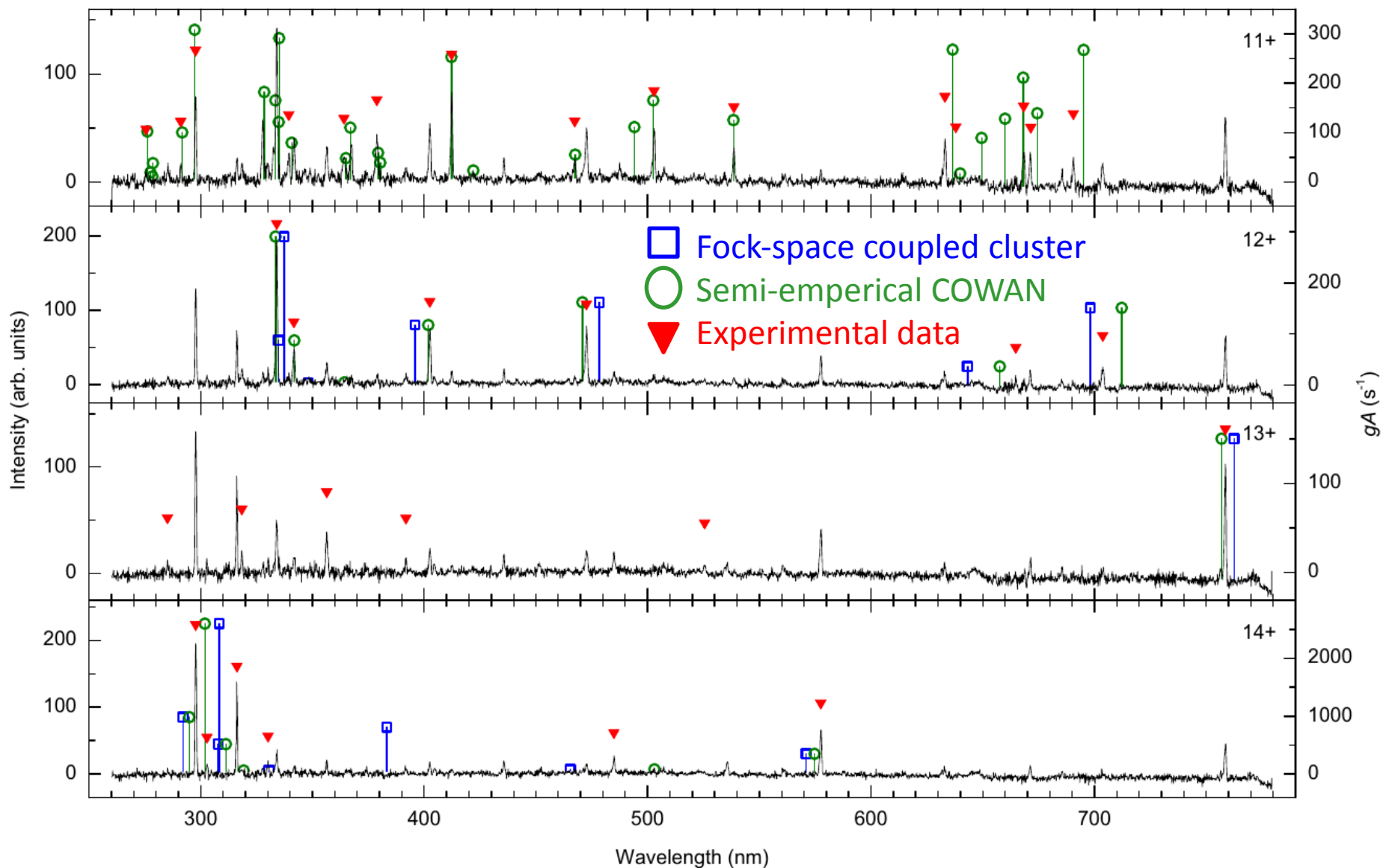
The electron beam energy can be tuned to produce the required charge state

$$E_e = E_{DT} - E_{gun} + E_{SC}$$

Electron impact *excitation*
→ fluorescence signal

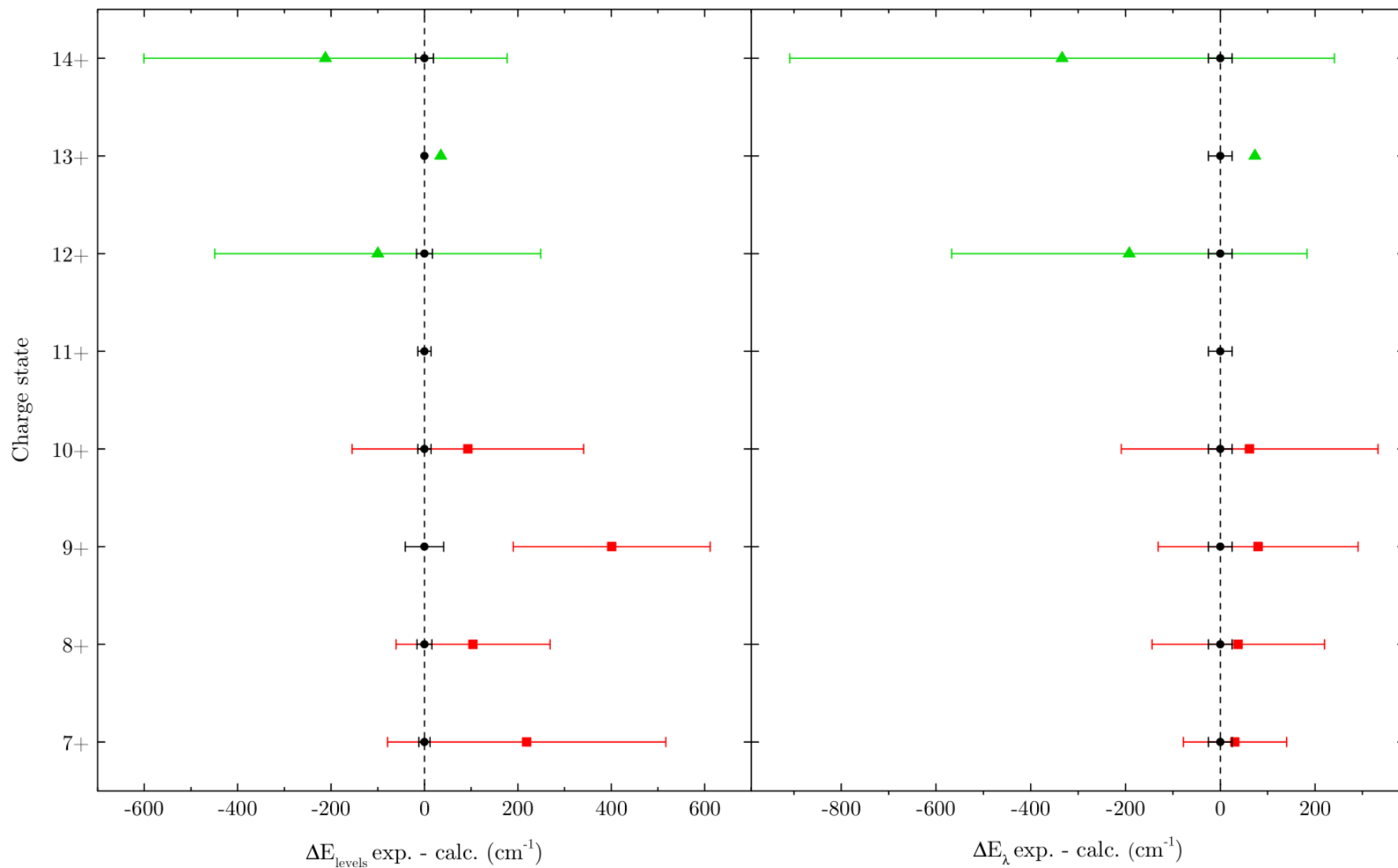






Windberger, A., *et al.* "Analysis of the fine structure of Sn 11+ – Sn 14+ ions by optical spectroscopy in an EBIT." *Physical Review A* 94.1 (2016): 012506.
 Torretti, F., *et al.* "Optical spectroscopy of complex open-4 d-shell ions Sn 7+ – Sn 10+." *Physical Review A* 95.4 (2017): 042503.

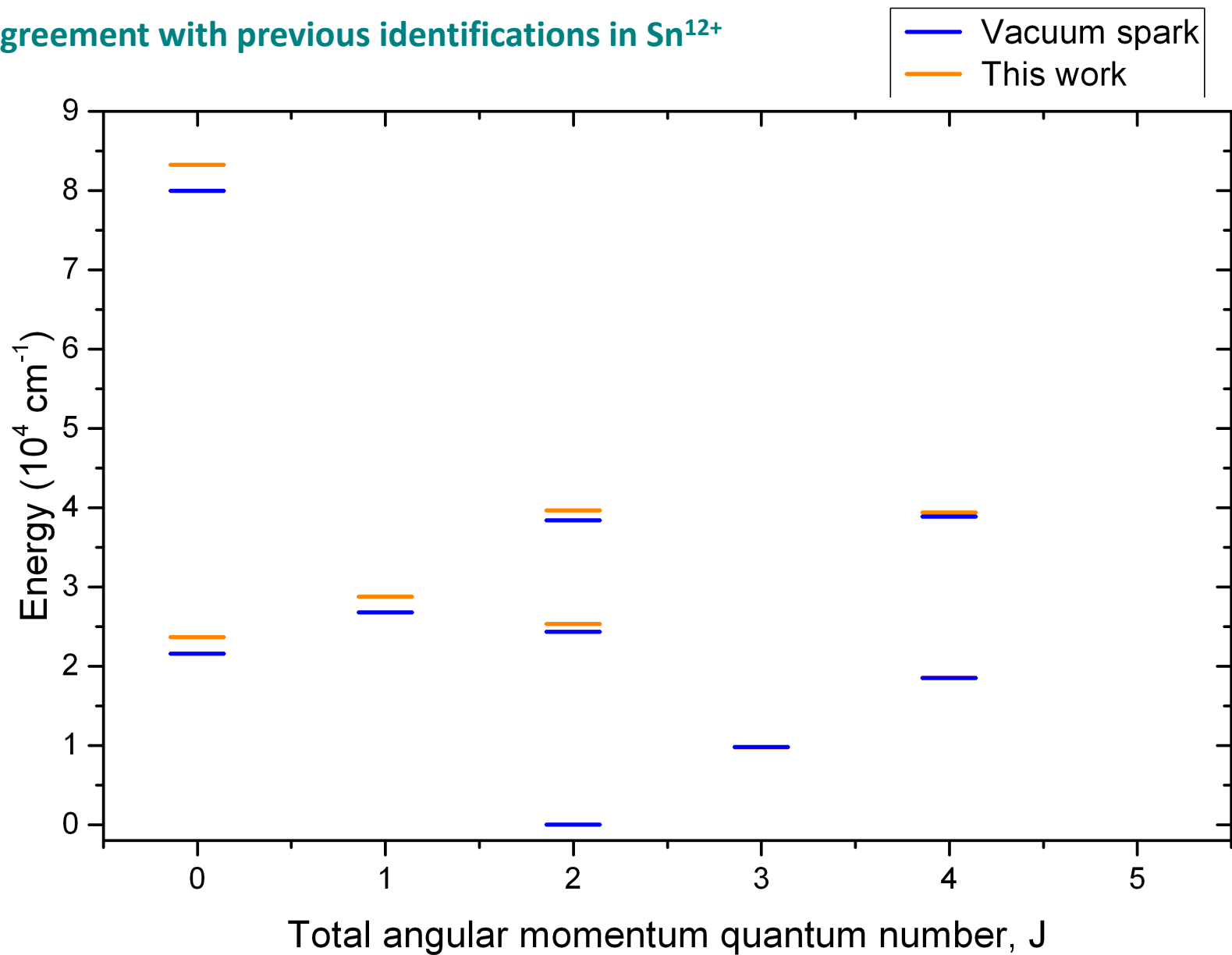
Comparison to *ab initio* predictions



▲ Fock-space coupled cluster (A. Borschevsky *et al.*)

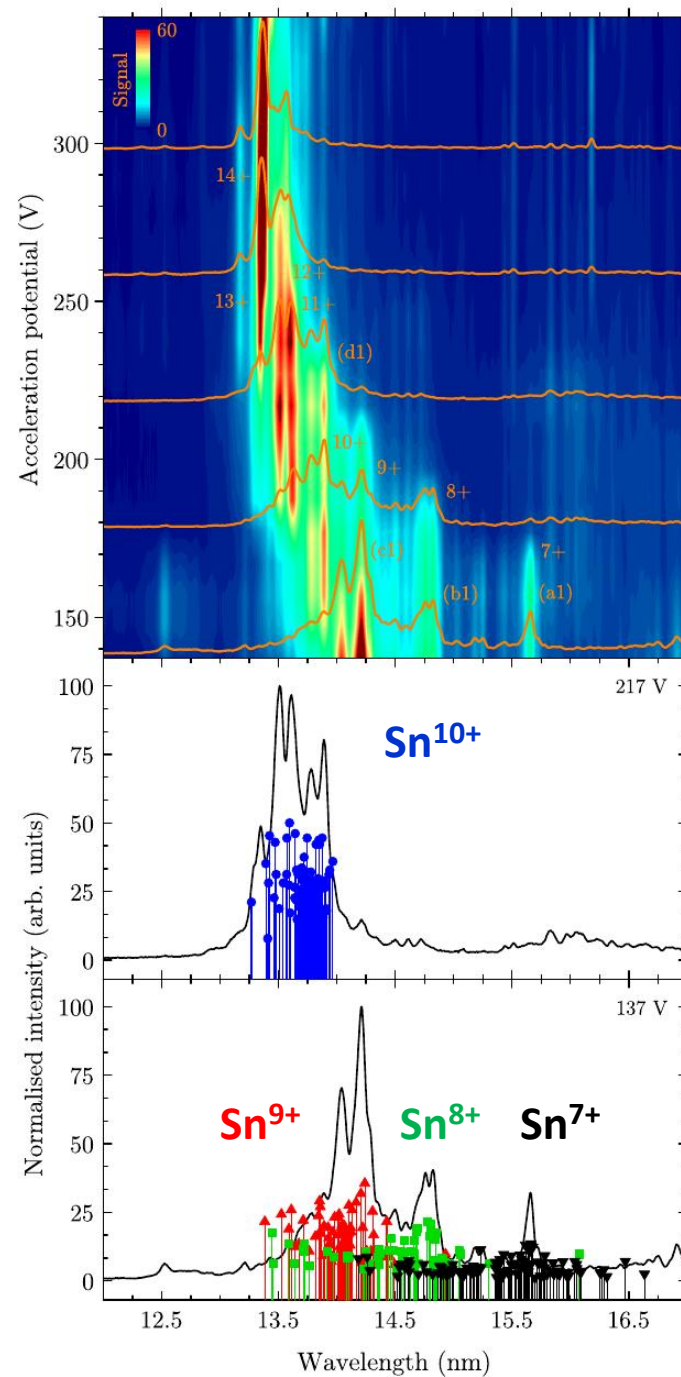
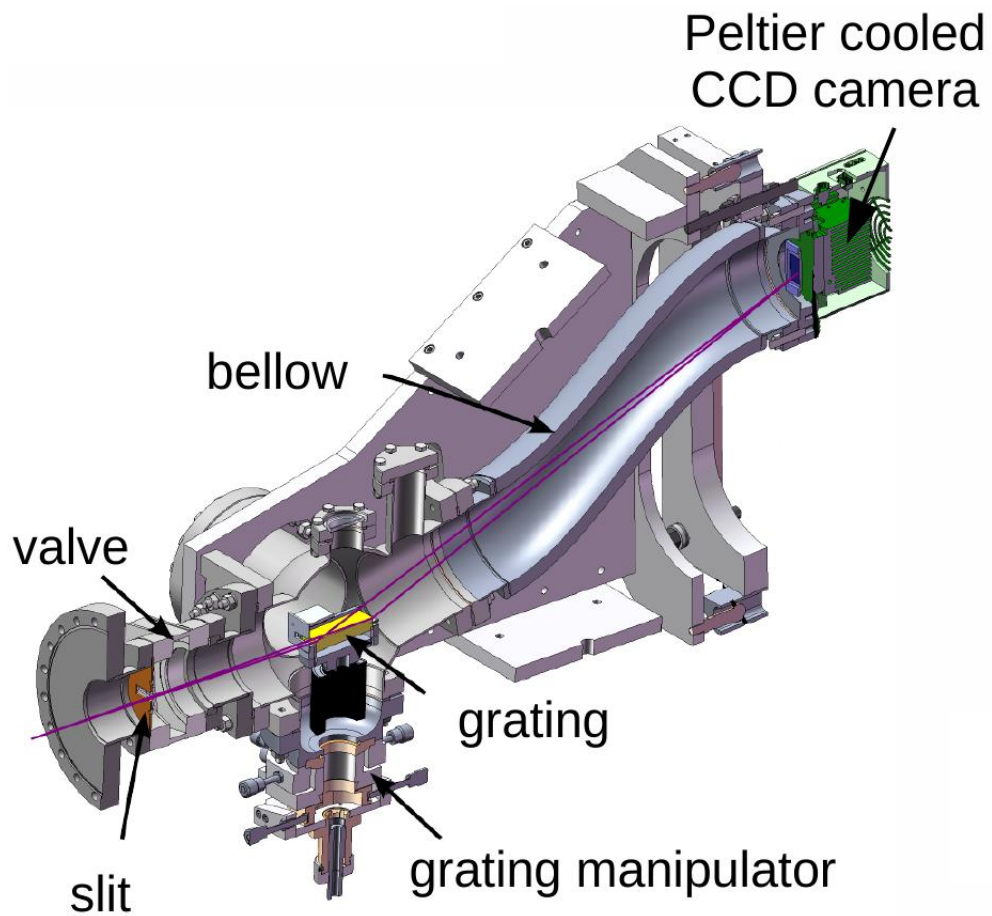
■ CI + MBPT (J. C. Berengut *et al.*)

Disagreement with previous identifications in Sn^{12+}

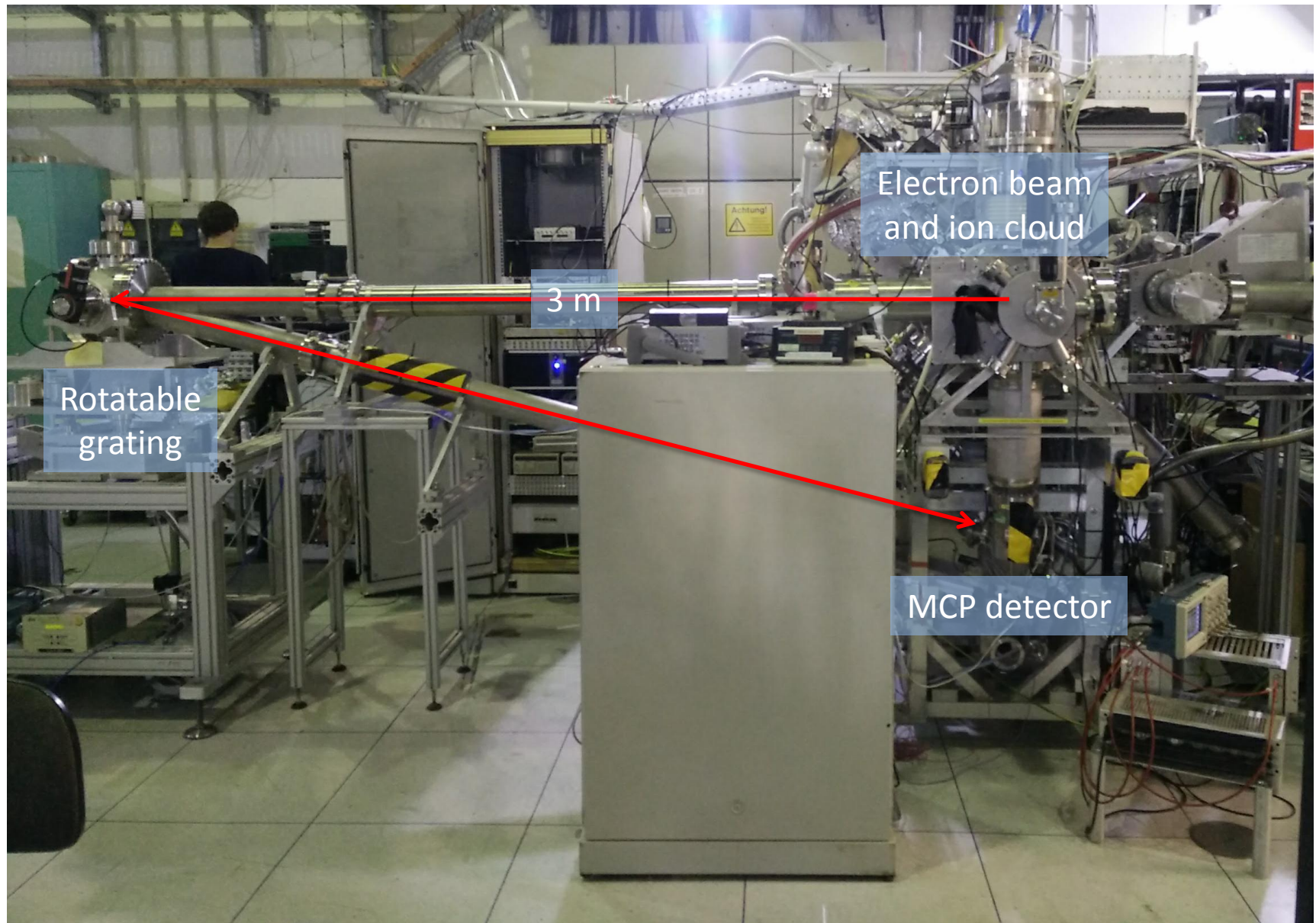


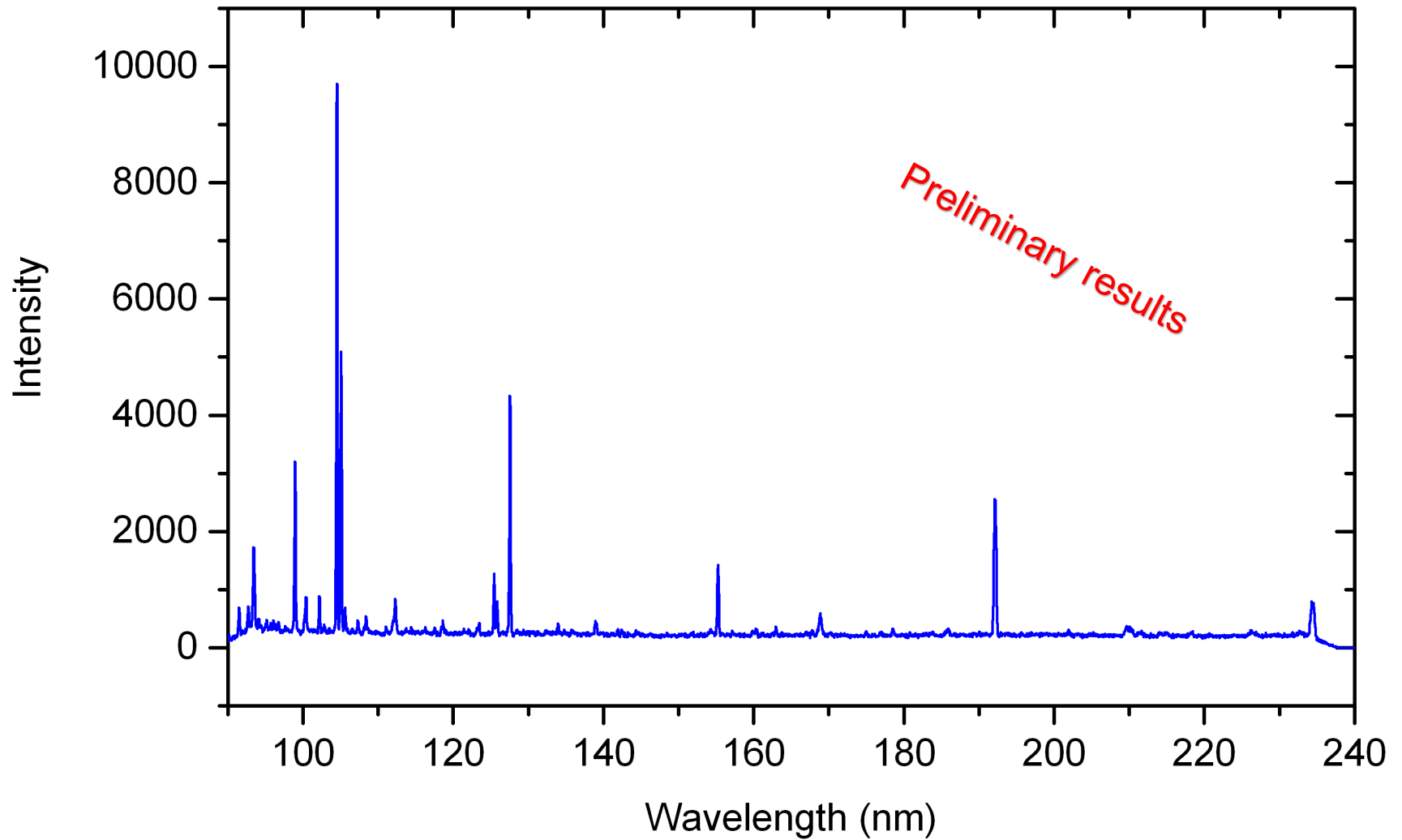
S. S. Churilov and A. N. Ryabtsev, Opt. Spectrosc. 100, 660 (2006).

S. S. Churilov and A. N. Ryabtsev, Phys. Scr. 73, 614 (2006).

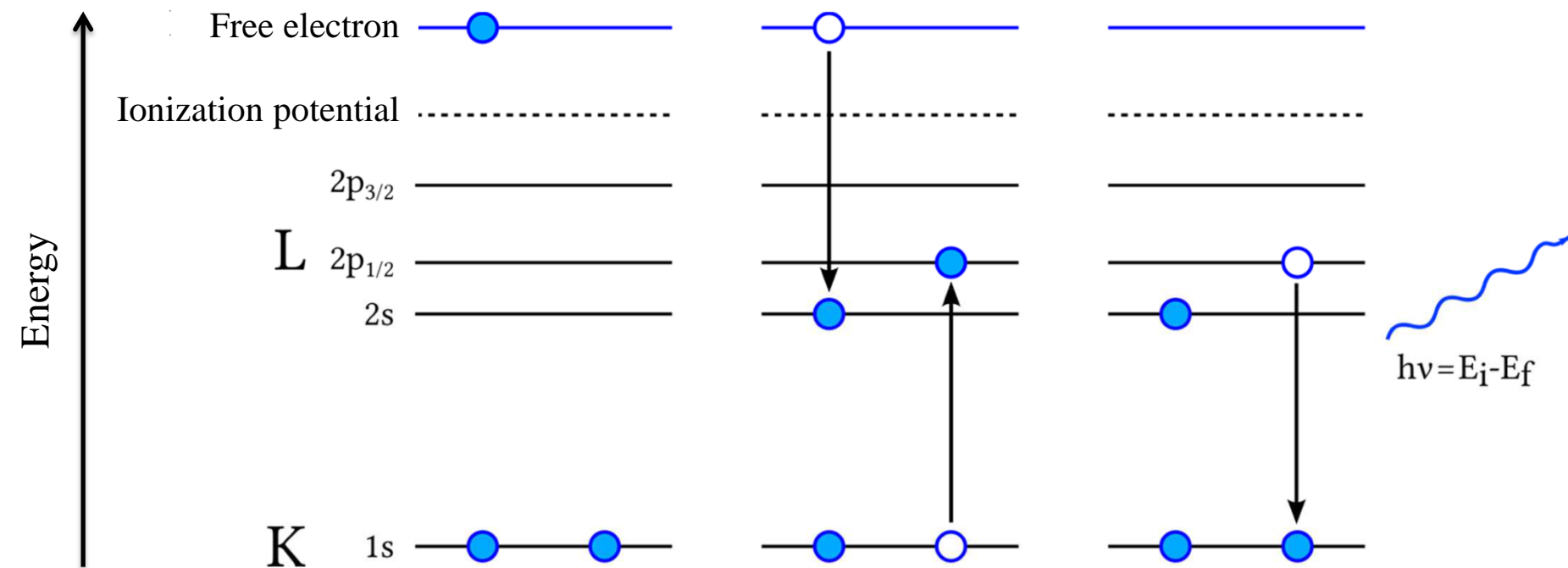


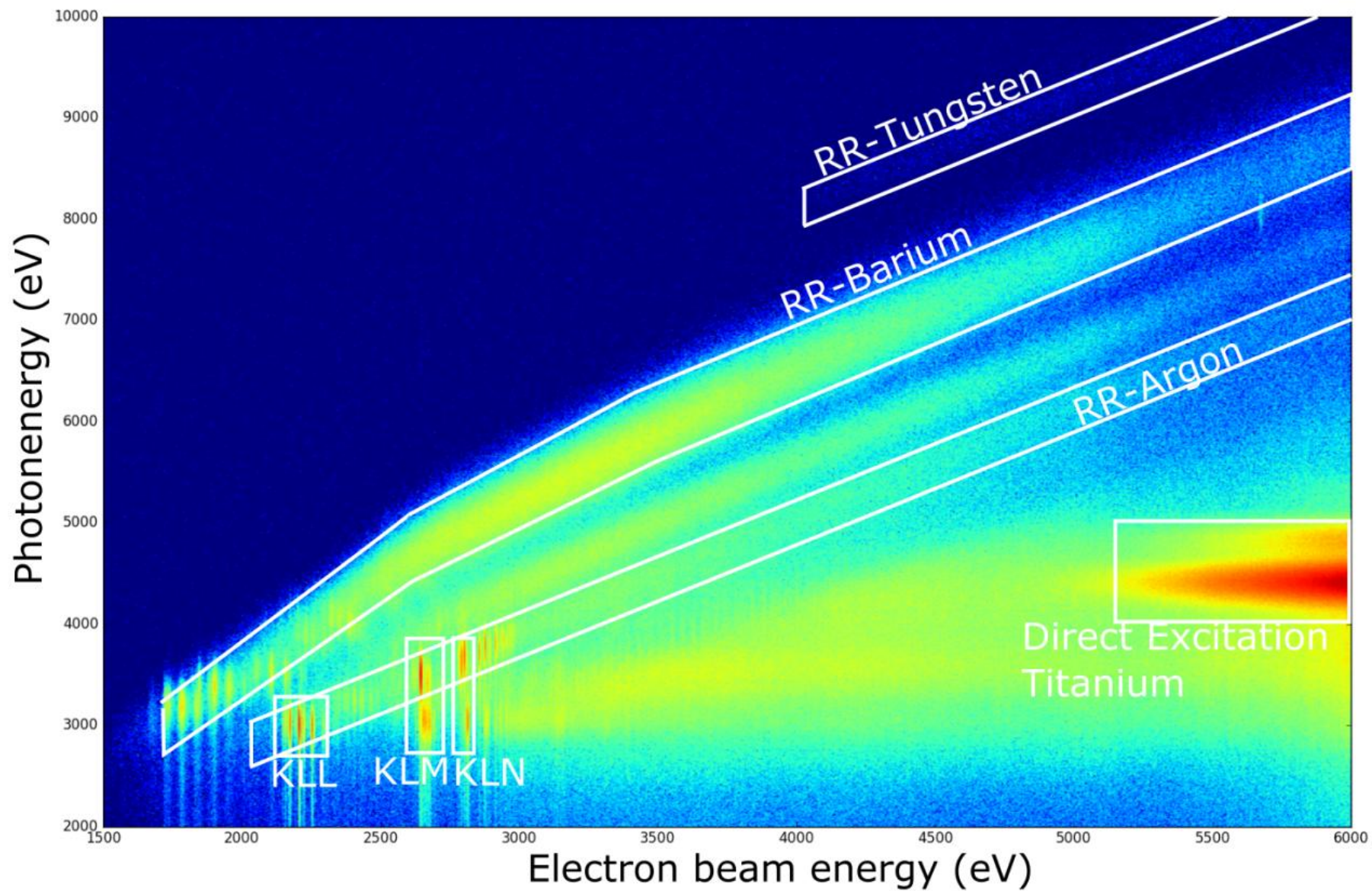
Spectroscopy in the range of 30 – 200 nm

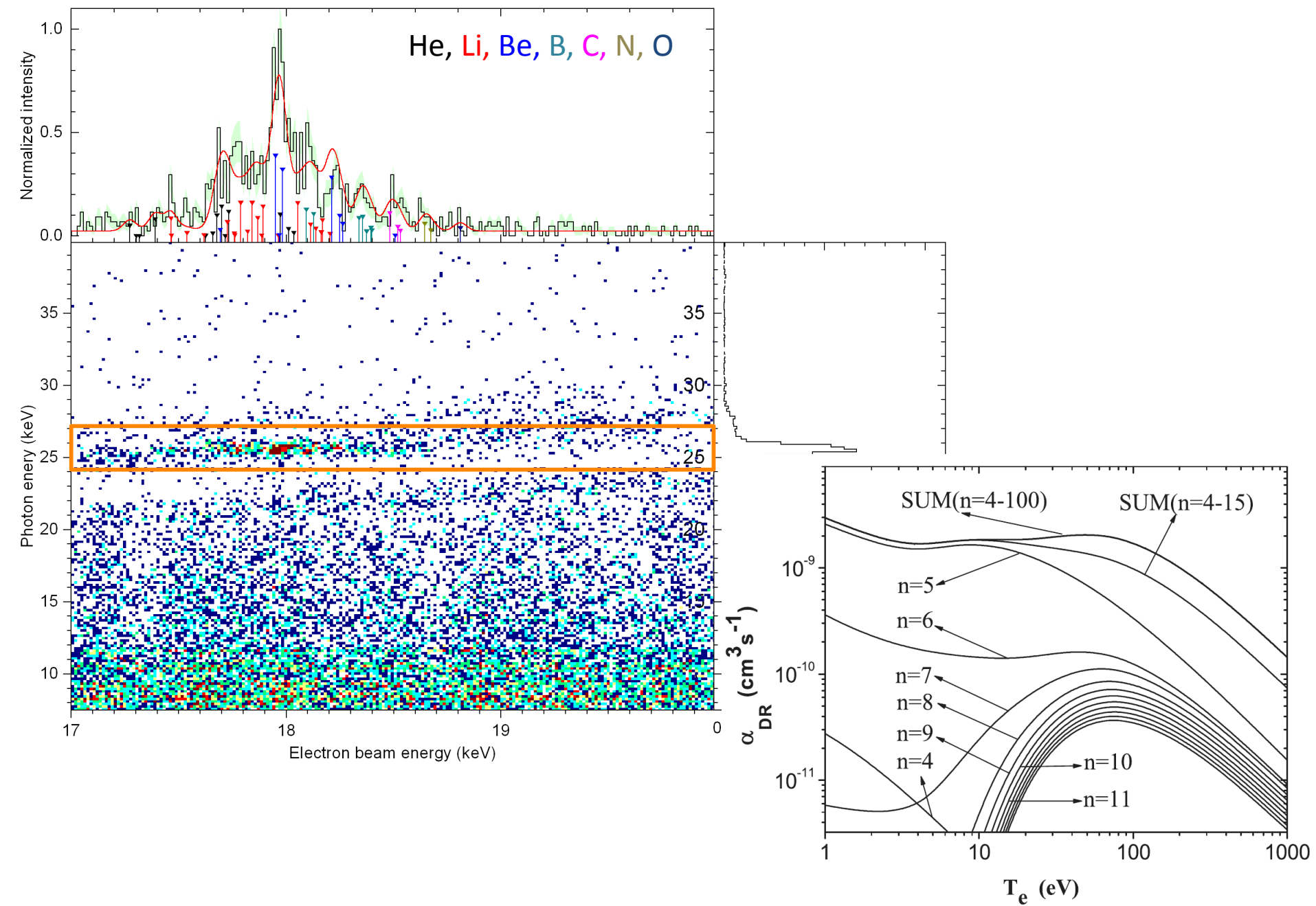




Dielectronic recombination studies







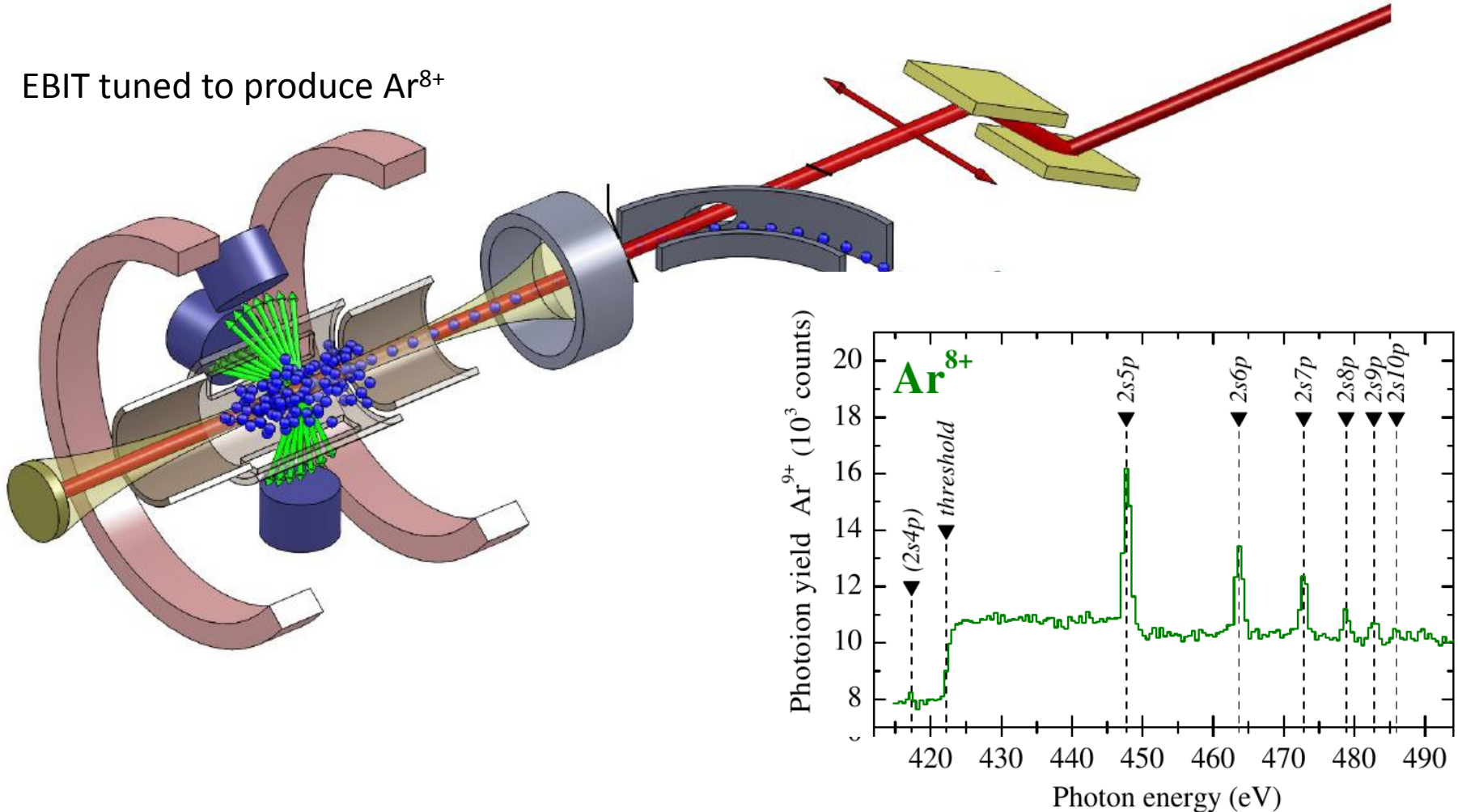
Fu, Y. B., *et al.* "Theoretical investigation of dielectronic recombination of Sn12+ ions." *Physical Review A* 83.6 (2011): 062708

Photoionization cross-section measurements

Photons from

- BESSY II 29-1600 eV
- PETRA III 5- 70 keV
- FLASH FEL 13-310 eV
- LCLS FEL 0.28 – 11.2 keV

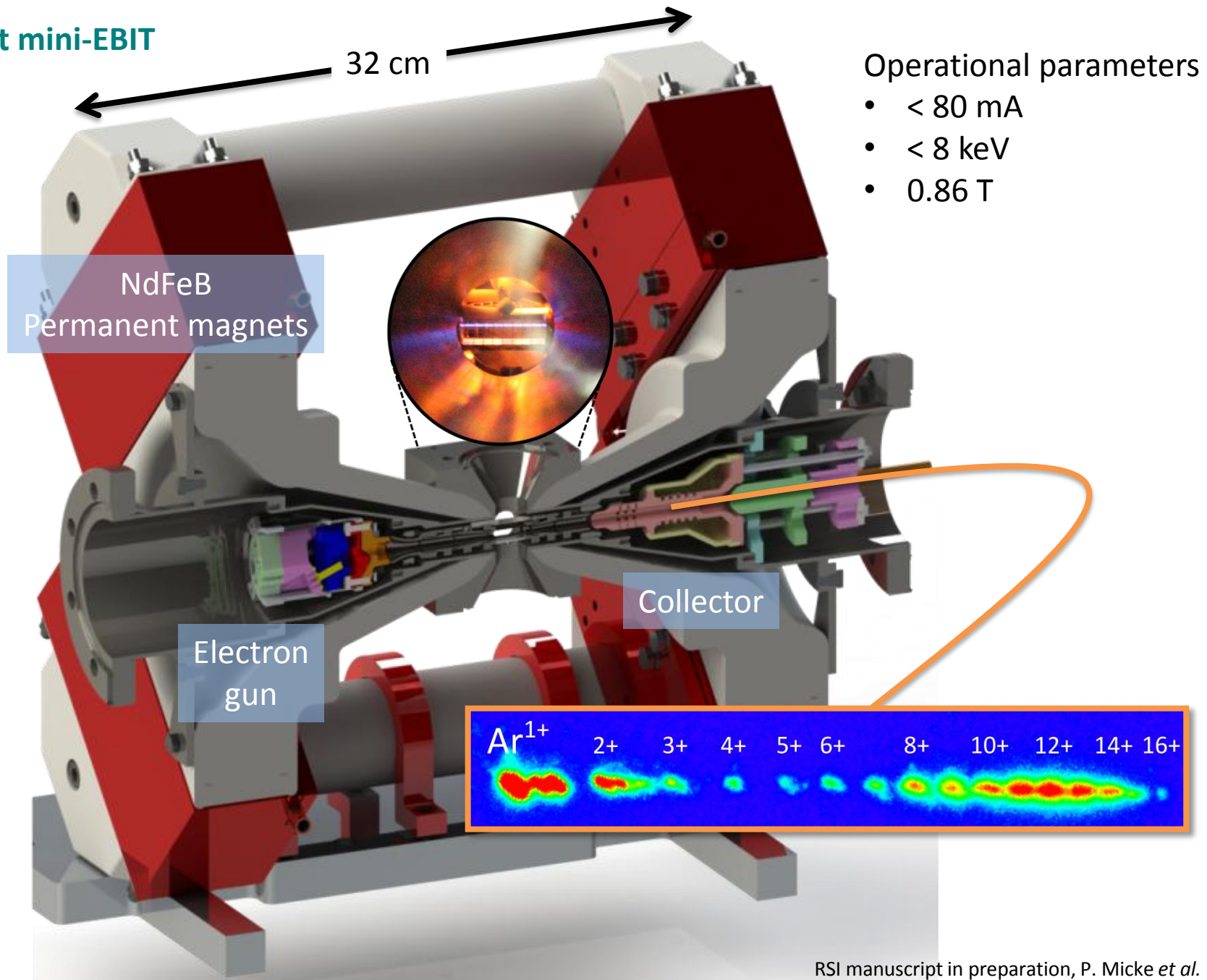
EBIT tuned to produce Ar^{8+}



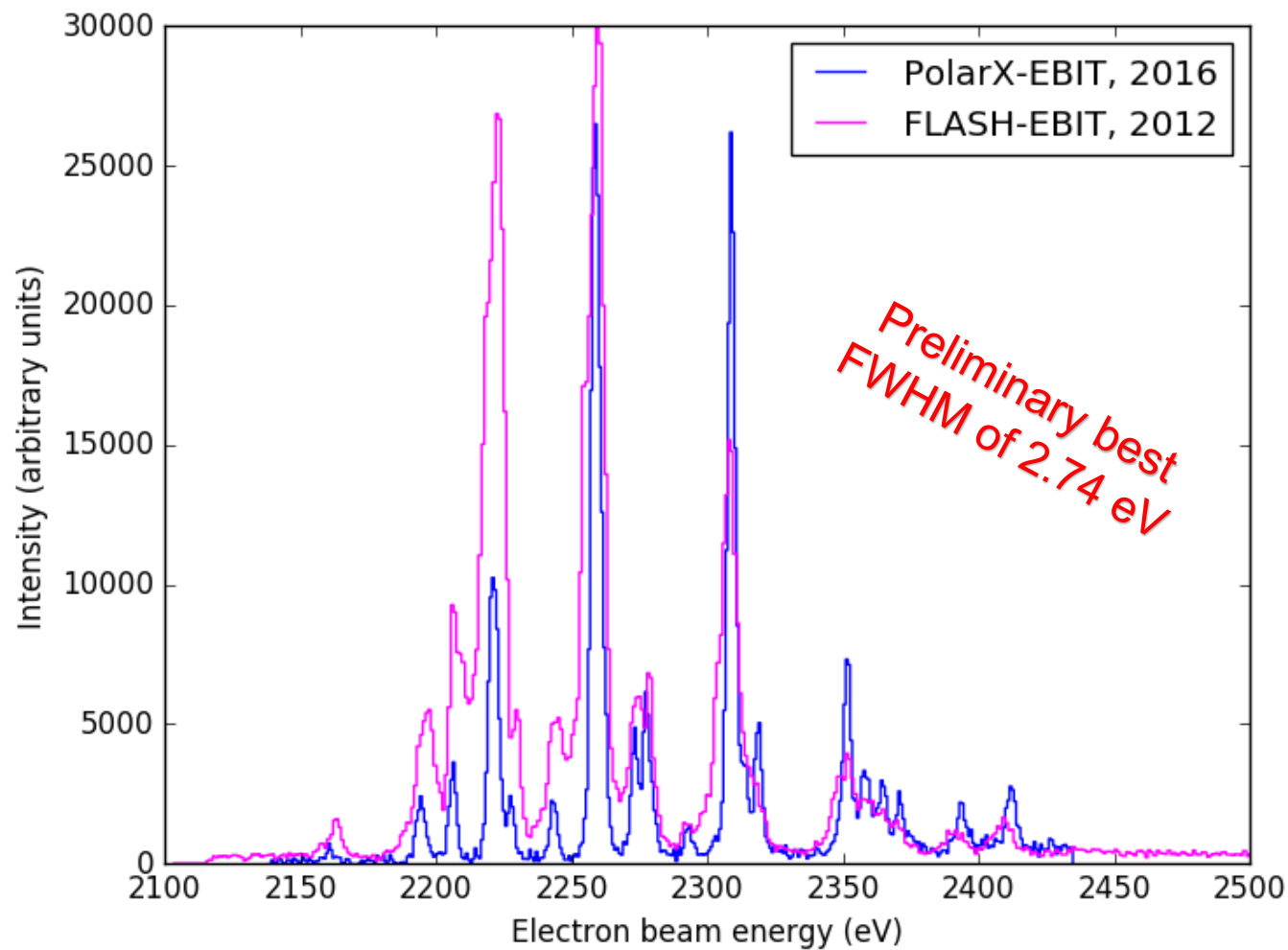
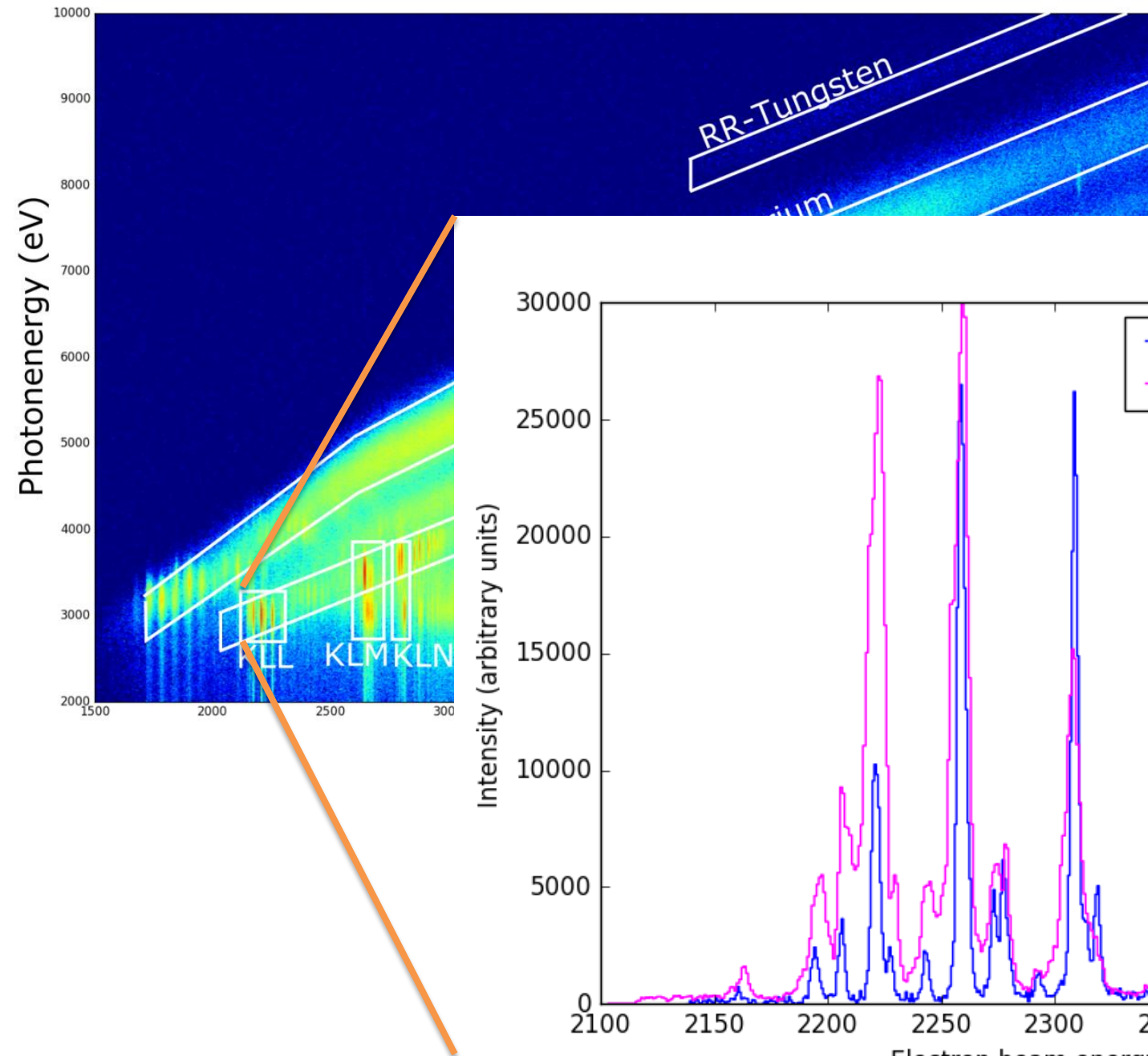
Simon, M. C., *et al.* "Photoionization of N^{3+} and Ar^{8+} in an electron beam ion trap by synchrotron radiation." *J. Phys. B.* 43.6 (2010): 065003

Simon, M. C., *et al.* "Resonant and near-threshold photoionization cross sections of Fe^{14+} ." *Physical review letters* 105.18 (2010): 183001

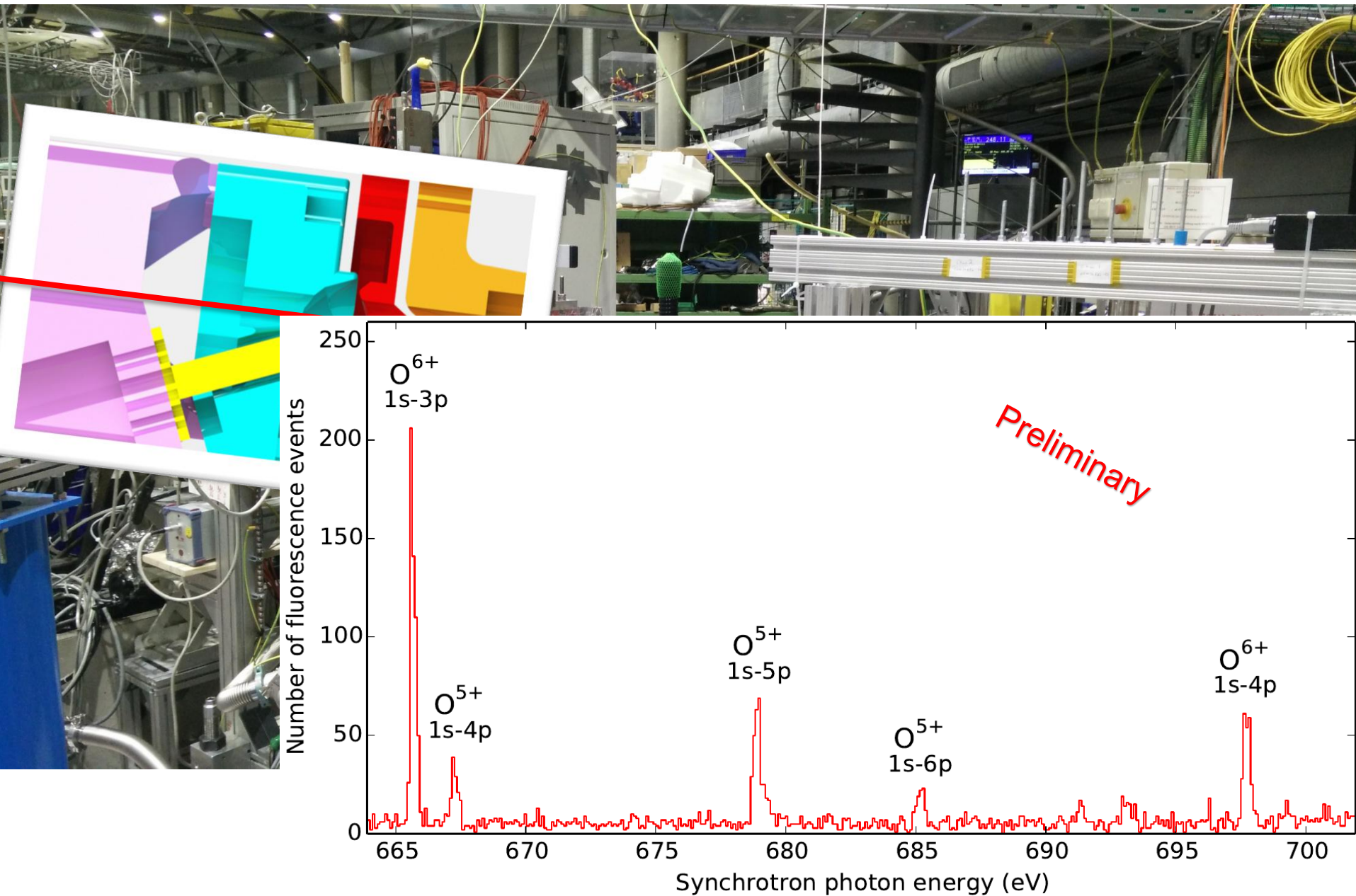
Low cost mini-EBIT



RSI manuscript in preparation, P. Micke *et al.*



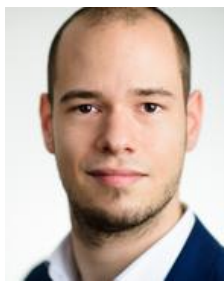
Recent beamtime at BESSY II



Acknowledgements

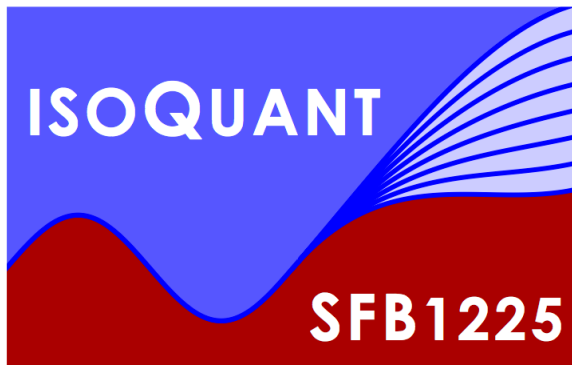
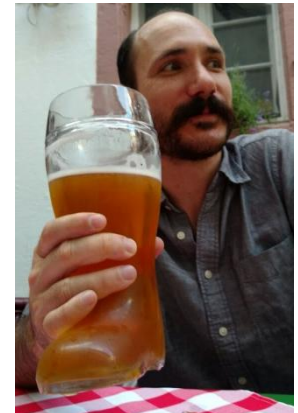
Experiment

- A. Windberger
- F. Torretti
- S. Dobrodey
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- S. Bernitt
- P. Micke
- J.R. Crespo López-Urrutia
- W. Ubachs
- R. Hoekstra
- O. O. Versolato



Theory

- A. Ryabtsev
- A. Borschevsky
- E. Kahl
- J.C. Berengut
- V. A. Dzuba
- E. Eliav
- U. Kaldor



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